SHIELDING STUDY OF BREMSSTRAHLUNG IN BULK MEDIA WITH 22 MEV ELECTRONS

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The space-energy distribution of bremsstrahlung in and through a bulk medium like a beam stop of the electron accelerator is important for the study of radiation shielding, residual activity and radiation damage of accelerator and target materials. We have recently published several papers on the spatial distributions of bremsstrahlung in water and water-iron[1], aluminum and iron[2] bombarded by 22 MeV electrons measured with our new method of determining bremsstrahlung spectrum from the activities induced in detectors by various photonuclear reactions. Those experimental results were compared with those calculated by our electron-photon cascade Monte Carlo code, TAURUS. The estimation of the spatial distribution of bremsstrahlung radiation in water, aluminum and iron by the TAURUS calculation gives the good agreement with our experimental results except for some poor experimental data.

To get more detailed information on the spatial bremsstrahlung distribution in a bulk medium, the photon flux $\phi(R,\theta)$ was calculated and integrated above 1 MeV in the θ direction at the transmission length R which is defined in fig. 1. Figure 2 shows the calculated flux distribution multiplied by the square of the length R^2, $R^2\phi(R,\theta)$ as a function of R for water, aluminum, iron and lead. As shown in fig. 2, the quantity $R^2\phi(R,\theta)$ obeys an exponential attenuation law having the same slope for every value of parameter θ for these four media except in the vicinity of the beam incident point. From fig. 2, the angular photon flux distribution $\phi(R,\theta)$ can be expressed as

$$\phi(R,\theta) = C\,\frac{e^{-\lambda\theta}\,e^{-\mu R}}{R^2} \qquad \text{for} \quad R \gtrsim R_0 \,, \qquad (1)$$

where R_0 = ~15 cm for water,
= ~ 4 cm for Al,
= ~ 1 cm for Fe and Pb.

The longitudinal flux distribution $\Phi(z)$ can be obtained by

$$\Phi(z) = \int_0^{r_{max}} \phi(R,\theta)\, 2\pi r dr \qquad (2)$$

which corresponds to the photon number above 1 MeV crossing a circle of radius r_{max} normal to the electron beam axis. The $\Phi(z)$ distributions along the axial depth z integrated from the $\phi(R,\theta)$ values in fig. 2 are shown in fig. 3 for several r_{max} values. In fig. 3, the $\Phi(z)$ distribution approaches to an exponential attenuation with increasing the r_{max} value.

The distribution $\Phi(z)$ is also possible to be obtained from eq.(1) and fig. 1 as follows;

$$\Phi(z) = 2\pi C \int_0^{\theta_{max}} e^{-\lambda\theta} e^{-\mu z/\cos\theta} \tan\theta \, d\theta \quad , \qquad (3)$$

where

$$\theta_{max} = \cos^{-1}\left(\frac{z}{\sqrt{r_{max}^2 + z^2}}\right) .$$

The good agreement between two $\Phi(z)$ values from eq.(2) and eq.(3) can be seen for $R \gtrsim R_0$ in fig. 3, except for z = 18.5 cm in iron. When r_{max} is infinitive, $\Phi(z)$ is the total photon number above 1 MeV crossing a plane normal to the beam axis and is found from fig. 3 as,

$$\Phi(z) = \int_0^\infty \phi(R,\theta) 2\pi r dr \quad \propto e^{-\alpha z} \qquad z \gtrsim z_0 \quad , \qquad (4)$$

where $z_0 \approx R_0$ for water and aluminum and $z_0 \approx 3$ cm for iron and lead. The value of α is approximated as $\alpha \approx 1.1\mu$.

References

1) T. Nakamura, T. Nishimoto and H. Hirayama, J. Nucl. Sci. Technol., 14 (1977) 31.
2) H. Hirayama and T. Nakamura, Nucl. Instr. Methods, 133 (1976) 355.

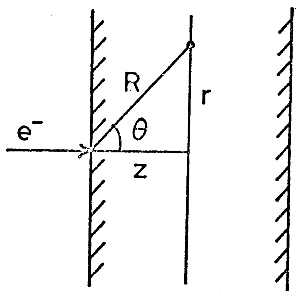

Fig. 1. Schematic diagram of a relation between space parameters

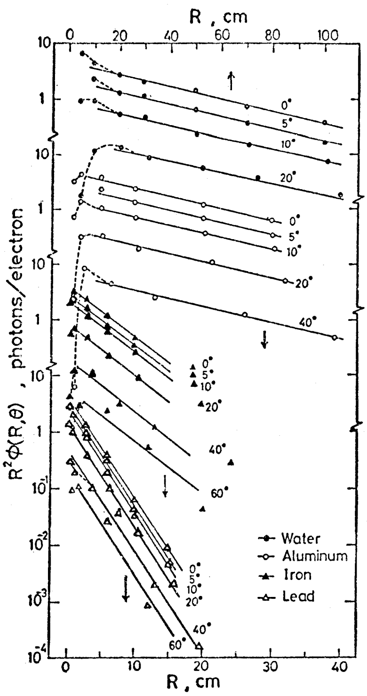

Fig. 2. Spatial distribution of photon fluxes integrated above 1 MeV as a function of R

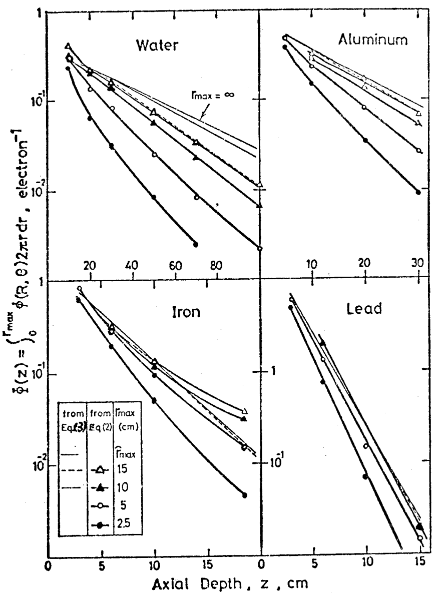

Fig. 3. Longitudinal distribution of photon fluxes for various r_{max} values